



Physical Sciences

Suppressing Ghost Diffraction in E-Beam-Written Gratings

The degree of periodicity of stitching errors is reduced.

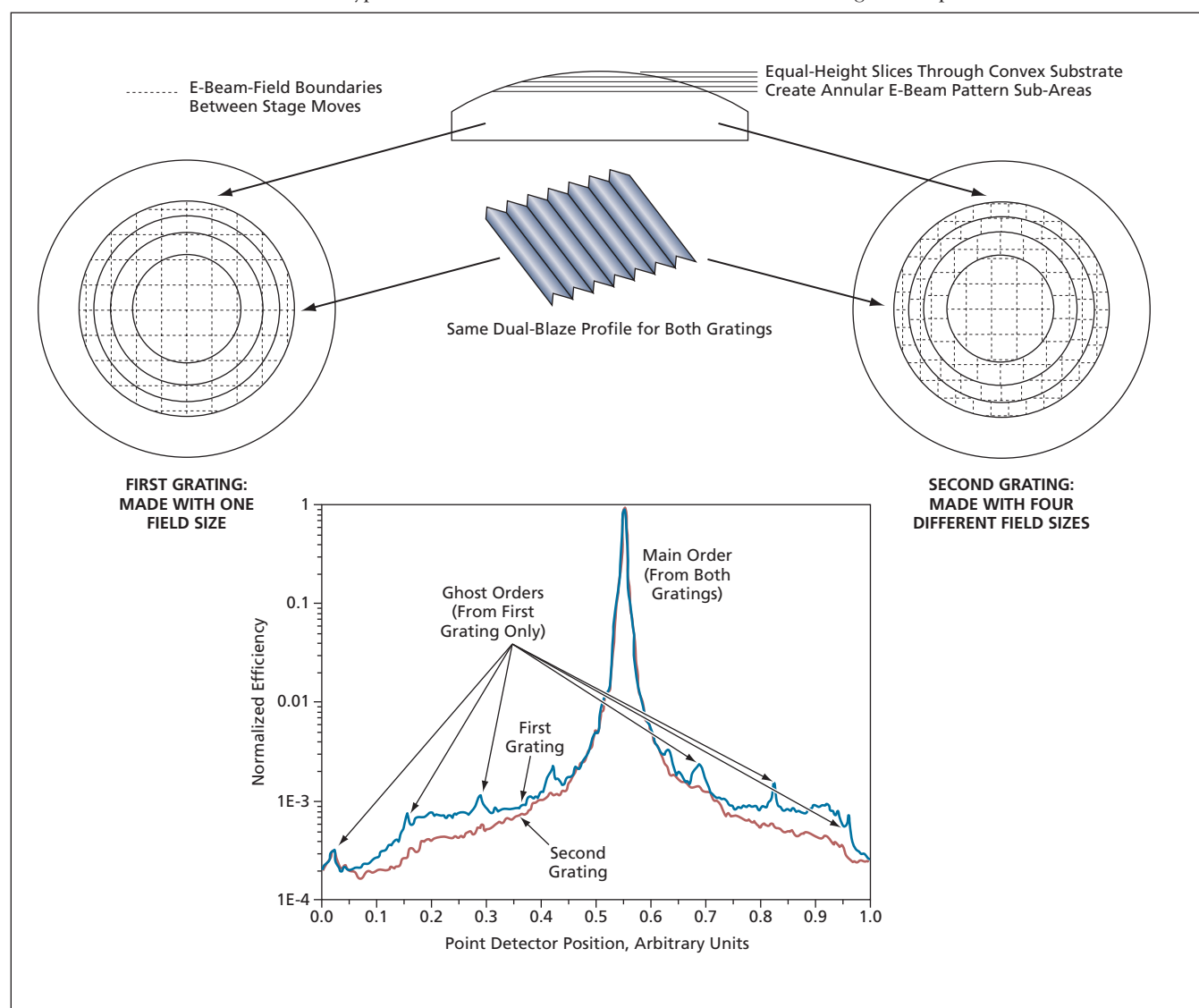
NASA's Jet Propulsion Laboratory, Pasadena, California

A modified scheme for electron-beam (E-beam) writing used in the fabrication of convex or concave diffraction gratings makes it possible to suppress the ghost diffraction heretofore exhibited by such gratings. Ghost diffraction is a spurious component of diffraction caused by a spurious component of grating periodicity as described below. The ghost diffraction orders appear between the main diffraction orders and are typi-

cally more intense than is the diffuse scattering from the grating. At such high intensity, ghost diffraction is the dominant source of degradation of grating performance.

The pattern of a convex or concave grating is established by electron-beam writing in a resist material coating a substrate that has the desired convex or concave shape. Unfortunately, as a result of the characteristics of electrostatic de-

flectors used to control the electron beam, it is possible to expose only a small field — typically between 0.5 and 1.0 mm wide — at a given fixed position of the electron gun relative to the substrate. To make a grating larger than the field size, it is necessary to move the substrate to make it possible to write fields centered at different positions, so that the larger area is synthesized by “stitching” the exposed fields.



The **Second of Two Convex Gratings** was divided into four annuli, within which the grating patterns were written with different field sizes. As a result, the second grating exhibited significantly less ghost diffraction.

Even though the mechanical stage used to position the substrate can be very accurate (positioning error of ≈ 20 nm or less), field-stitching errors occur, causing underexposures or overexposures that manifest themselves, after development of the resist, as increases or decreases in grating thickness along the field boundaries. Because all the fields are of the same size, the stitching errors form another grating that has a period equal to the field size. Hence, the light scattered from the field boundaries adds coherently: this is ghost diffraction.

The modified scheme for electron-beam writing is based on the concept of reducing the degree of periodicity of the stitching errors. In this scheme, the overall grating area is divided into sub-areas within which the grating patterns are written in differently sized fields. For a typical convex or concave grating, the

sub-areas are most easily defined as annular areas that correspond to equal-height slices through the substrate (see figure). Hence, the grating pattern in each annulus is written with a different field size.

The ghost order intensities are proportional to the square of the scattering amplitudes. Hence, if N different field sizes are used, the intensity of ghost diffraction can be expected to be reduced to approximately N^{-2} times the intensity obtained with a single field size.

To test this concept, two nominally identical gratings were fabricated. The pattern of the first grating was written by stitching together fields of the same size over its entire area, while the pattern of the second grating was established by use of four different field sizes. Whereas the ghost diffraction from the first grating was clearly noticeable, the

intensity of ghost diffraction from the second grating was so low as to be undetectable against the diffuse-scattering background.

This work was done by Daniel Wilson and Johan Backlund of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Refer to NPO-41302, volume and number of this NASA Tech Briefs issue, and the page number.

Target-Tracking Camera for a Metrology System

Angular measurements are updated at a rate of hundreds of hertz.

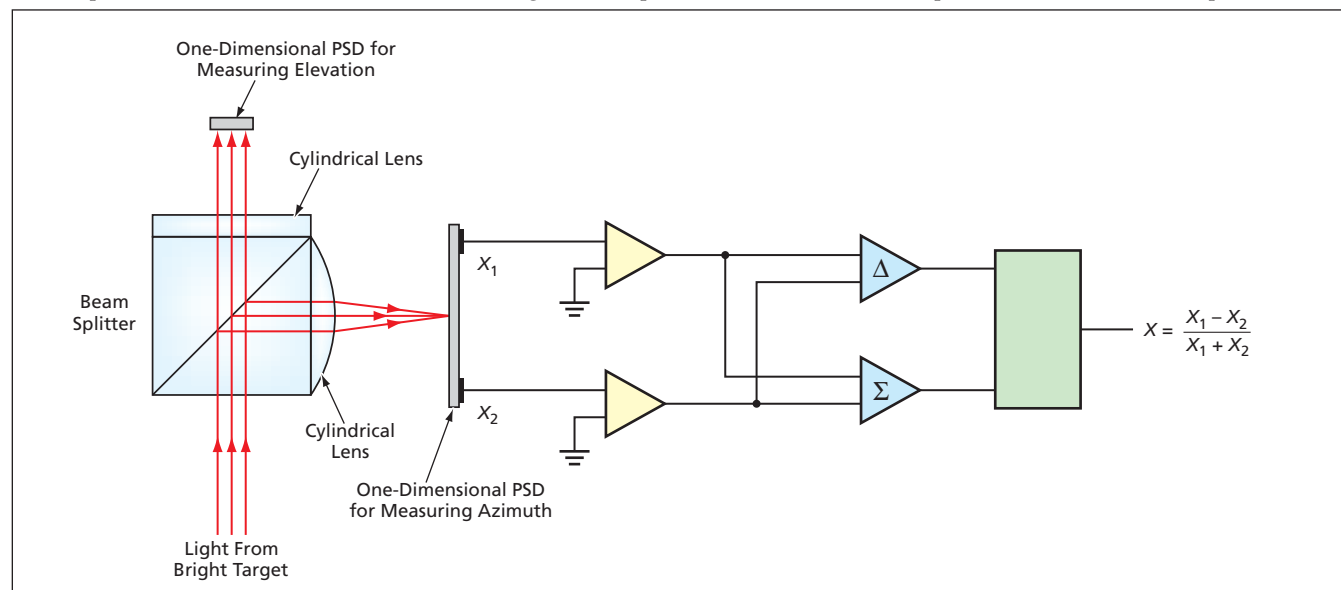
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An analog electronic camera that is part of a metrology system measures the varying direction to a light-emitting diode that serves as a bright point target. In the original application for which the camera was developed, the metrological system is used to determine the varying relative positions of radiating elements of an airborne synthetic-aperture-radar (SAR) antenna as

the airplane flexes during flight; precise knowledge of the relative positions as a function of time is needed for processing SAR readings.

It has been common metrology system practice to measure the varying direction to a bright target by use of an electronic camera of the charge-coupled-device or active-pixel-sensor type. A major disadvantage of this practice arises from the

necessity of reading out and digitizing the outputs from a large number of pixels and processing the resulting digital values in a computer to determine the centroid of a target: Because of the time taken by the readout, digitization, and computation, the update rate is limited to tens of hertz. In contrast, the analog nature of the present camera makes it possible to achieve an update rate of



The **Optics and Electronic Circuitry** of the camera, shown here in simplified schematic form, provide two analog signals proportional to the horizontal and vertical angular displacements of the bright target.